Loss Reduction in Microstrip Antenna Using Different Methods

Alpesh Nema[1#], D.K. Raghuvanshi[2#], Priyanka Raghuvanshi[3*]

[#]*Department of Electronics & Communication Engineering MANIT-Bhopal, India.*

[*]*Department of Electronics & Communication Engineering R.G.P.V.–Bhopal, India*

Abstract – **This paper presents a survey of various techniques to reduce the losses in the microstrip patch antenna. The designed antenna structures include several methods to reduce antenna losses in a microstrip antenna. Some of the methods such as multiple layered patches in microstrip antenna also increase its directivity by 4.2 dB. By using double negative substrate mutual coupling can be reduced by 14.2dB at the resonant frequency of 4.55GHz. The concept of an engineered conductor method which is based on using multiple laminated thin conductors is used for enhancing their gain by minimizing the ohmic loss. Experimental results are discussed to validate the concept.**

Keywords – Microstrip antenna, ohmic loss, directivity, mutual coupling, resonant frequency.

I. INTRODUCTION

The physical size of the electronic components has been reduced to a good extent in the past few years, thus, pressurizing the antenna researchers to develop miniaturized antennas. Microstrip patch antenna is widely used due to being compact, conformal, and low cost. The quality of the materials like copper, gold and substrate which are going to be used in microstrip antenna defined the conductor loss and dielectric loss. Mainly three types of losses i.e. conductor loss, dielectric loss and surface wave loss is responsible for lower gain of a patch antenna. Material and substrate thickness are responsible for dielectric loss while the high permittivity and low substrate thickness of material are the reasons for the origin of surface wave loss. The excellent quality of conductor and dielectric substrate [2] are extremely important to reduce the conductor loss and dielectric loss which improves the gain of the antenna. The gain of the patch antenna can be further enhanced by suppressing surface waves [3].

This paper presents a review of various techniques of loss reduction in microstrip antenna.

II. LOSS REDUCTION SURVEY

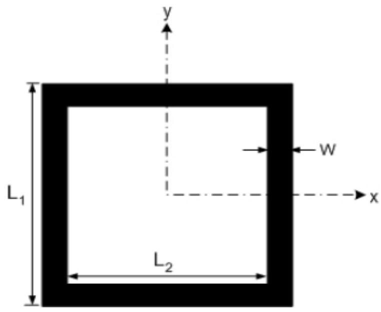
Extensive research work has been done on the design of microstrip antennas to use its several advantages such as light weight, low volume, low cost, planar configuration, compatibility with integrated circuit. The researchers still continue further efforts to reduce the size of regular patch antennas.

Paper by Saeed I. Latif, C. Shafai, and Lotfollah Shafai [1] presented loss reduction technique by using multiple copper layers microstrip antenna is discussed in section 3.1. Paper by Ali Farahbakhsh and Shahram Mohanna and Saeed Tavakoli [4] suggests the use of hexagonal patches to reduce the return loss and mutual coupling in microstrip antenna array which is going to discuss in section 3.2. Paper by Salma Mirhadi and Manoochehr Kamyab [5] describes about mutual coupling reduction of microstrip antenna array using double negative substrate is discussed in section 3.3. Paper by Mohsen Salehi, Ahad Tavakoli [6] presented mutual coupling reduction method in microstrip patch antenna using the defected ground structures (DGS) which is going to discuss in section 3.4 .

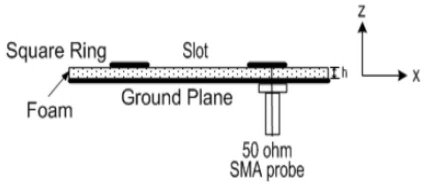
III. BRIEF DESCRIPTION OF STRUCTURES FOR LOSS REDUCTION IN MICROSTRIP ANTENNA.

A. Multi-Layered Patches to Enhance Antenna Directivity

Firstly, the microstrip square ring antenna, shown in Fig. 1, with size of the ring L1=60mm W=5mm, i.e. L2/ L1=0.84, operates at 1.41 GHz on a foam substrate with thickness h=1mm. A square microstrip patch of the length of 60mm resonates at 2.5 GHz on the same substrate. Thus, the square ring is a miniaturized antenna, and its properties are discussed in [7]. However, the ring has two edges, the inner and outer, where the currents become excessively large, especially when W is narrow, the variation of current on the ring becomes very large, and causes excessive ohmic losses, which reduce the antenna gain. To overcome this problem, we have used multiple thin copper layers (as depicted in Fig. 2) rather than a single layer of thickness typically ranging from 5 to 3.5μm in commercial substrates.

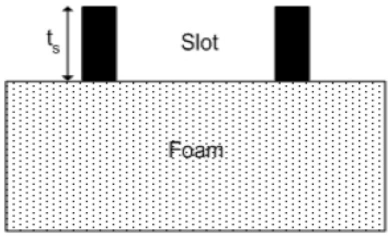


(a)

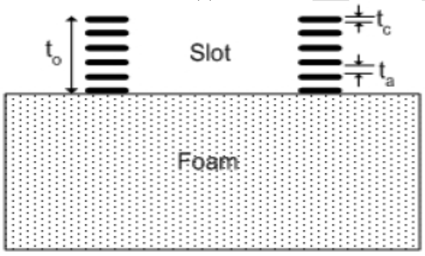


(b)

Fig. 1 Geometry of square-ring antenna on a foam substrate: (a) top view, (b) side view.



(a)



(b)

Fig. 2 Side view of a square ring antenna on a foam substrate, (a) with a single solid copper layer,
(b) with multiple copper layers.

For a single copper layer, when the thickness is less than the skin depth (δ=3μm for Cu at 1.41 GHz), the directivity is very low, and it increases as the thickness approaches the skin depth, but as the thickness increases beyond the skin depth, the directivity remains constant at 4.56dB.

An increase of 2.36dB in the directivity is found with six copper layers, having a thickness of 11μm. With Cu thickness (t_c) 3μm and air gap (t_a) 3μm, (approximately equal to the skin depth in copper), a peak directivity of 8.84dB is found for five layers having an overall thickness of 27μm. This indicates an increase in the directivity of 4.28dB, compared to a single layer case having the same thickness.

B. The Use of Hexagonal Patches to Reduce the Return Loss and Mutual Coupling

The array antenna used here consists of four elements arranged in a 2 by 2 array. All elements are placed on one layer structure which has three conductive layers and two dielectric substrates. As seen in Fig. 3, patches are placed in the upper layer, the middle layer is the feed line layer and the lower layer is assumed to be an infinite ground plane. The thickness of substrates (D1, D2) is 0.5mm and their relative permittivity is 3. The patches are fed by proximity feeding method by 50Ω feed lines. The width of feed lines is 1.25mm. The array structure and its dimensions are illustrated in Fig. 2. The antennas are designed for X-band at 8GHz. The length and width are calculated to be 10.096mm and 12.42mm, respectively. The distance between elements in X and Y directions are 14.08mm and 12.03mm, respectively.

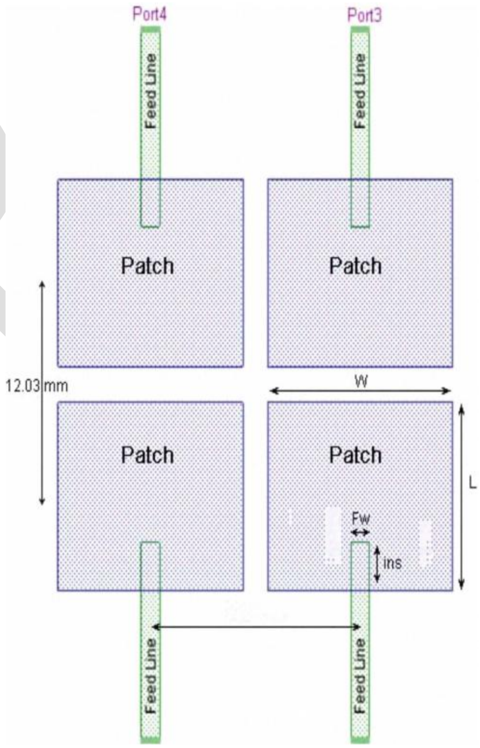


Fig. 3 Structure of array antenna

The patch shape is determined by values of W and L and also by vertical position of PI and P2. The patch is assumed to be vertically symmetrical so the position of left and right points is equal. The design aim is to compute the parameters W, L, PI and P2, to decrease the mutual coupling and return loss of the array structure with a fixed resonant frequency.

Compared with the parameters in the initial rectangular patch, the reflection coefficient and mutual coupling coefficients with the hexagonal patch are shown in Fig. 4 and Fig. 5, respectively.

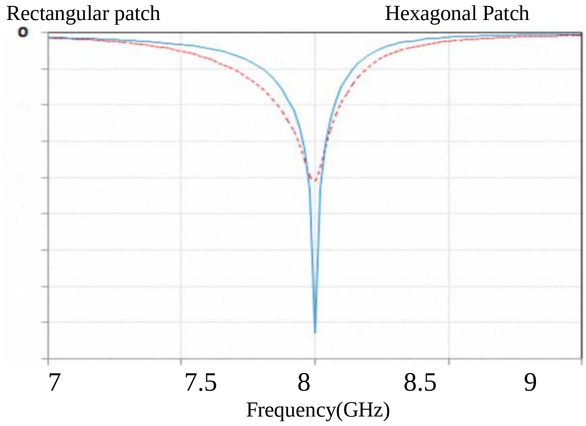


Fig. 4 Reflection coefficient of rectangular and hexagonal patch array antennas.

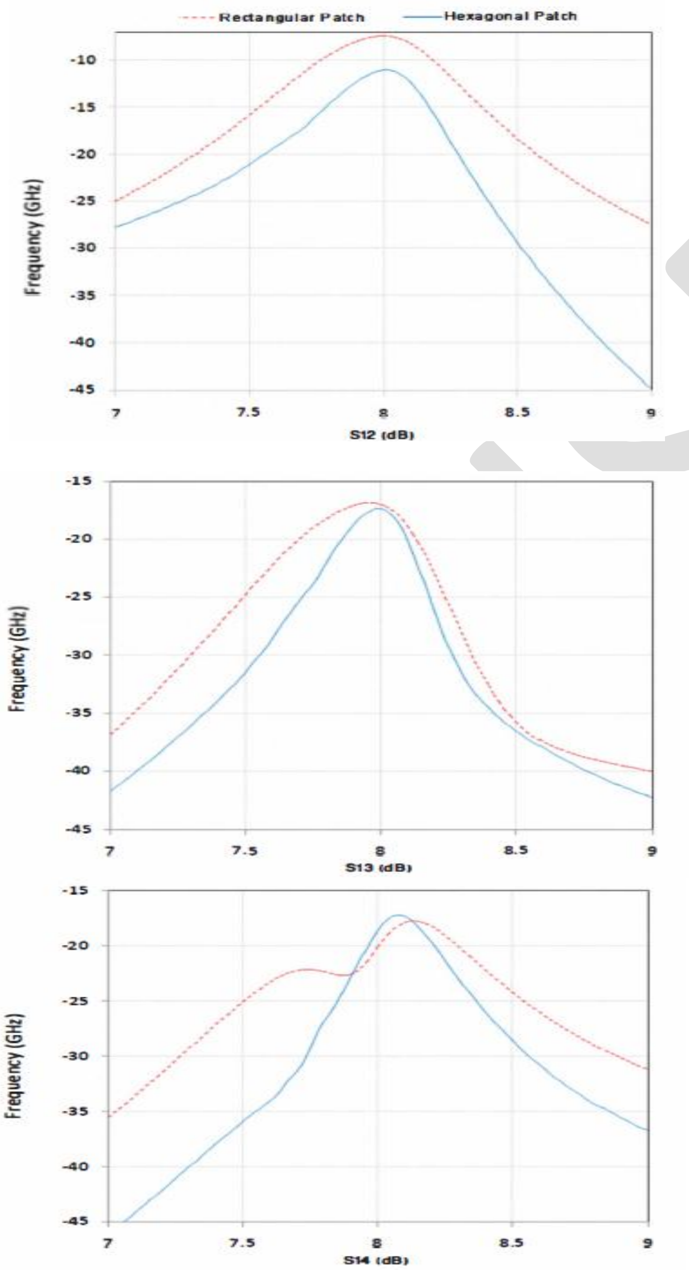


Fig. 5 Mutual coupling coefficients of rectangular and hexagonal patch array antennas

C. Mutual Coupling Reduction of Microstrip Antenna Array Using Double Negative Substrate

One of the main problems in the microstrip antenna array is the mutual coupling between antenna elements which is due to the surface waves. It leads to the performance degradation such as impedance mismatch, high side lobe level and deviation of the radiation pattern from the desired one. The surface wave coupling gets reduced only by 3dB when the distance between the antennas is doubled [8]. A DNG substrate is a solution to avoid surface wave propagation in the microstrip antenna. The front (*E*-plane) and side (*H*-plane) coupling of two patch antennas on a conventional substrate and on a DNG substrate have been compared using the finite difference time domain (FDTD) full wave analysis. The comparison between the results from patch antennas on a conventional substrate and patch antennas on a DNG one shows a remarkable reduction in the mutual coupling and the coupling values of less than -30dB can be achieved.

1) H-plane coupling: The selected distance between antennas is 21mm corresponding to 0.31λ at the resonant frequency. The size of the ground plane is 74.2 × 36.6mm. The conventional antenna shows a strong mutual coupling of −7.25dB, while the DNG antenna exhibits coupling of −33.4dB (less than −30 dB) at the resonance, which is 26.15dB lower than the conventional one.

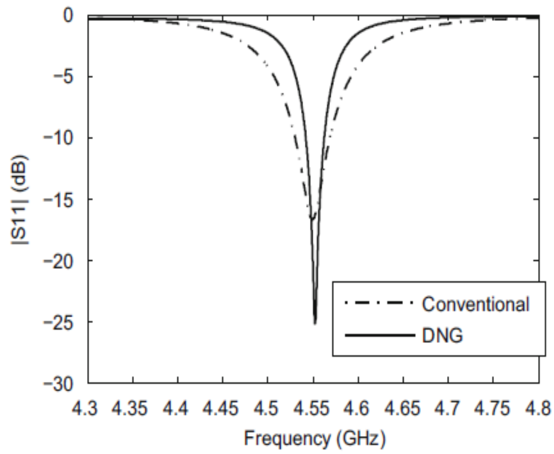


Fig. 6 FDTD results of the return loss of the patch antenna printed on a conventional and DNG substrate.

2) E-plane coupling: In this case, the antenna's parameters remain the same as earlier, but the distance between antennas has been changed to 24.5mm corresponding to 0.37λ at the resonant frequency. The size of the ground plane is 49 × 57mm. The mutual coupling of the conventional antennas at the resonance is −19.1dB. In comparison, the mutual coupling of the DNG antennas is only −33.3dB. Therefore, 14.2dB reduction of mutual coupling is achieved at the resonant frequency of 4.55GHz.

D. Mutual Coupling Reduction Method in Microstrip Patch Antenna Using Defected Ground Structure (DGS)

Fig. 7(a) shows the geometry of a dumb-bell shaped DGS etched on the ground plane of a conventional 50Ω microstrip transmission line with a dielectric constant of 10.2 and thickness 50mil. Using an FDTD algorithm, the *S*-parameters of the conventional and defected ground microstrip lines are calculated as depicted in fig.8. DGS microstrip line shows band-stop behaviour with an attenuation pole at 6 GHz. The presence of a bandgap for such a structure is used to improve the design characteristics of many microwave circuits. Identical substrates with thickness of 50 mil and permittivity of 10.2 when used in simulations as shown in fig. 9 by a layout of 2-element microstrip antenna array on a defected ground plane of 80mm × 60mm *(*1.6λ0×1.2λ0*)* at a design frequency of 6 GHz. By a trial and error method, the optimized DGS dimensions for a bandgap at the resonant frequency of the antenna are found. The square lattice dimension *a* × *b* is optimized to 3.6mm × 4mm with the etched gap distance of 0.9 mm.

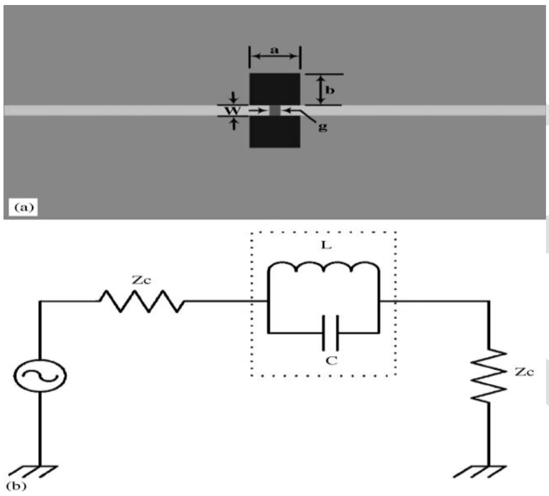


Fig. 7 (a) Microstrip transmission line with the DGS unit etched on the ground plane (*a*=*b*=4.2mm, *g*=0.8mm and *w*=1.2mm). (b) Equivalent circuit of the DGS microstrip line

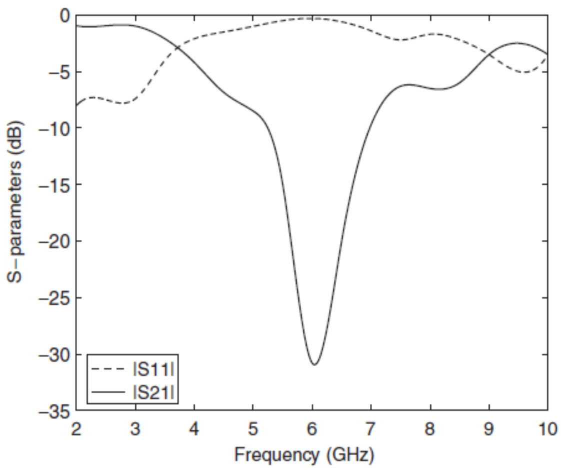


Fig. 8 FDTD simulated *S*-parameters of the DGS microstrip transmission line.

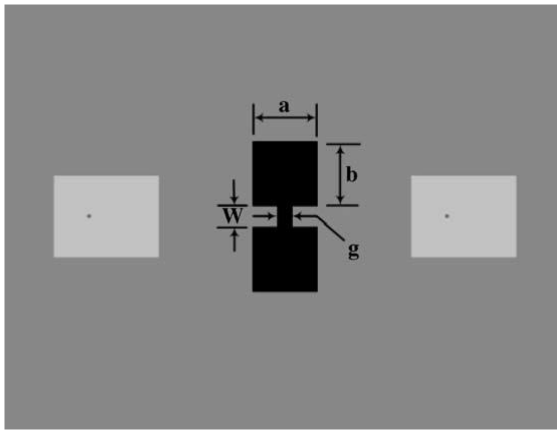


Fig. 9 *E*-plane coupled probe fed microstrip patches on a defected ground plane

IV. CONCLUSION

Various designs for loss reduction in microstrip antenna have been proposed. All designs have significantly reduced antenna losses as compared to the corresponding conventional microstrip antenna. In first design the gain was increased and the method showed a great promise for directivity enhancement of the small antennas, by reducing the resistive losses in stacked multiple thin copper layers. In second design, proposed an effective solution to decrease the return loss and mutual coupling in a two-dimensional microstrip array antenna. The third technique uses a DNG substrate as a solution to avoid surface wave propagation in the microstrip antenna. In fourth method a low mutual coupling design for a two element microstrip antenna array was proposed. It used a dumbbell shaped defect on the ground plane of the antenna inserted between the patches creating a bandgap in the operational frequency band of the antenna. All four designs decrease the loss significantly but second design enhances both gain and directivity of antenna also.

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